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Geographically specific transport emission inventories

Review of feasibility for road and rail transport

Working paper developed by CE for EEA

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Summary

One of the objectives of the European Environment Agency (EEA) is to monitor the state of the European Environment by means of a set of environmental indicators. Quantitative knowledge of environmental impacts is an important input for policy making while monitoring developments provides useful insight in the effectiveness of implemented policy measures. In this context emission inventories at specific geographical levels (i.e. sub-national, regional, etc.) may help to create insight in regional origins of emissions, to create insight in regional distribution of impacts, and to provide input for regionally oriented emission abatement policies, e.g. for regions where policy measures taken at the EU or national level yield insufficient reductions or a too slow rate of reduction.

Inventories of transport emissions at various sub-national geographic (regional) levels require regional data on the distribution of traffic flows across time and space as well as characteristics of the vehicle fleet. In some areas such information is well developed, e.g. for air traffic, but for other transport sectors the situation is unclear. This study explores the availability of relevant regional data for road and rail transport and sketches a 'blue print' of the for the development geographically specific emission inventories for these two transport sectors. It pulls together the information already available and points out the data gaps.

A review of data availability through a limited number of national data sources shows that information on relevant regional transport performance indicators may be available in national statistics, but is apparently not shared through international statistical databases. A more in-depth review of data availability at the national level is necessary to draw conclusions on the possibility of setting op geographically specific transport emission inventories on the basis of existing data. Such a review could be carried out by Eurostat in cooperation with national statistics institutes and could also comprise activities to further work out a methodology for regional data collection. The database and modelling developed in the ETIS project seems to provide a useful starting point for setting up a Europe-wide inventory of regional transport emissions.

Emission factor models for road transport allow geographic variation of a large number of variables relating to e.g. fleet composition, road types and traffic situation, and geographic and climatic conditions. Available emission factors for trains are less versatile and sophisticated than the emission factor models available for road transport.

Overall it can be concluded that the possibilities for geographical differentiation of transport emission inventories for road and rail are currently limited by the availability of regional statistics on vehicle fleet composition and transport performance on various road types rather than by the limitations of the available emission factors model.

1 Introduction

1.1 Goal and scope of the project

A previous project on data for non-road modes of transport identified an opportunity to develop geographically specific emission inventories[1]. In general emission inventories are made at the national level. For various purposes insight in overall emissions at other geographical scales, e.g. at the level of provinces or types of regions, could be of interest.

Inventories of emissions at a regional level require regional data on the distribution of traffic flows across time and space as well as characteristics of the vehicle fleet. In some areas such information is well developed, e.g. for air traffic, but for other transport sectors the situation is unclear.

The purpose of this study is to explore the availability of relevant regional data for road and rail transport and to sketch a 'blue print' for the development of geographically specific emission inventories for these two transport sectors. The study pulls together the information already available and points out the data gaps.

It should be noted that, in view of the available budget, this study has the nature of a quick scan, especially with respect to the review of availability of regional data. Relevant data may be available through a large number of national or regional sources, which could not all be reviewed in the context of this study.

This project has been carried out as part of the framework contract EEA/IAR/006/01 (*'Expert assistance in the area of transport and environment'*).

1.2 The purpose of geographical differentiation of emission inventories

The aim of this project on geographical differentiation of emission inventories is to see how far one can get in describing transport emissions from the bottom up, meaning from the vehicle level upwards. Such information can obviously be aggregated to city, county, regional or national level, or whichever other aggregation is desired. The purpose of this project is to get a grip on the availability of traffic related data that can serve as a basis for such an inventory.

One of the objectives of the European Environment Agency (EEA) is to monitor the state of the European Environment by means of a set of environmental indicators. Quantitative knowledge of environmental impacts is an important input for policy making while monitoring developments provides useful insight in the effectiveness of implemented policy measures. In this context emission

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1 *Policy and data on non-road transport modes*, H.P. (Huib) van Essen et al. CE Delft 2006, on behalf of EEA.

inventories at specific geographical levels (i.e. sub-national, regional, etc.) may serve the following purposes:

- Create insight in regional origins of emissions.
- Create insight in regional distribution of impacts.
- Provide input for regionally oriented emission abatement policies, e.g. for regions where policy measures taken at the EU or national level yield insufficient reductions or a too slow rate of reduction.

1.3 General considerations on calculation of emissions

Calculation of the overall transport emissions for a country or region is always based on the product of a transport performance variable and an emission factor:

Overall emissions = Σ transport performance x emission factor

These two, however, can be defined in different ways and can by themselves also be further differentiated.

Transport performance can be defined at the level of vehicles or at the level of the transported loads (people or goods). Transport statistics generally record transport performance in vehicle kilometres travelled. This information can be combined with emission factors expressed in grams per kilometre. If transport performance is expressed in passenger km or tonne km, this information needs to be multiplied by emission factors expressed in grams per passenger km or per tonne km. Many transport models generate data in terms of transported loads and distances, so working with this definition provides easy connection to those models. The availability of geographically specific data on transport performance is one of the essential issues in geographical differentiation of emission inventories.

Emission factors are in first instance generated at the vehicle level and per type of road (e.g. urban / rural / highway or more detailed breakdowns for cars). On the basis of measurements and modelling, emissions in grams per vehicle km are generated for a variety of relevant vehicle types and road types. Combined with information on load factors these emissions per vehicle km can be translated to emission factors per passenger km or per tonne km. Generating (average) emission factors per passenger km or per tonne km requires underlying calculations with data or assumptions on fleet composition and the distances driven by different vehicle types.

Both emission factors and transport performance can be expressed at various aggregation levels:

- Total over all vehicle types and road types.
- Differentiated per vehicle type.
- Differentiated per road type.
- Differentiated per vehicle type and road type.
- Differentiated per vehicle type, per road type and for different traffic and/or ambient conditions (ambient temperature, other climatic conditions, level of congestion, etc.).

With each further level of disaggregation the calculation of the total regional or national emissions becomes a more complex sumproduct.

1.4 Structure of this report

The structure of this report is based on the above discussed division between transport performance variables and emission factors. Chapter 2 explores the availability of regional data on transport performance. Possibilities for regional differentiation of emission factors are explored in chapter 3. A synthesis of the results and conclusions are provided in chapter 4.

2 Availability of regionally differentiated data on rail and road transport flow and fleet

2.1 Introduction

Overall transport emissions for a country or region are calculated on the basis of transport performance and emission factors. Transport performance can be defined at the level of vehicles or at the level of the transported loads (people or goods). If transport performance is expressed in passenger km or tonne km, this information needs to be multiplied by emission factors expressed in grams per passenger km or per tonne km. If expressed in vehicle km, it needs to be multiplied by emission factors expressed in grams per vehicle km. Many emission factors are available in all 3 units mentioned ((grams/pass-km), (grams/tonne-km) and (grams/vehicle-km)).

However, national and regional data on transport performance appears in many other units also. These alternative variables, like (number of passengers), (number of km's), (tonnes loaded) and many others are useful indicators for various monitoring and transport research purposes, but are not directly applicable to the calculation of national or regional emissions. However, on the basis of such data for a regional scale and assumptions about the relation between these variables and the relevant transport performance indicators, national emission data can to some extent be disaggregated in an indicative approach by looking at regional distributions of these other transport indicators.

Therefore, expression of transport performance in terms of vehicle-km, passenger-km or tonne-km is highly preferred for both national and regional emission inventories. In the case of road transport these performance indicators are preferably specified per vehicle type (e.g. passenger car, van, truck, bus, etc.), technology class (fuel type and emission class) and road type (urban, rural, highway). For rail transport similar subdivisions are useful (e.g. urban train, intercity, high speed train, freight train, etc.). Unfortunately the inventory of the availability of indicators on transport performance at the regional level, as reported in this chapter, shows that these data are not readily available through data sources at the European level. Region-specific data expressed in other units appear to be more widely available (see Table 1 for a selection of reported units).

2.1.1 Approach

In order to gather information on data availability on transport indicators on a regional level, first of all a European approach was taken. I.e. European level sources were consulted to extract regional data. As in these sources many relevant transport indicators were found to be missing on a regional level for many countries, as a second step also some national sources were consulted. Indeed, additional regional data often was found to be available through national sources. There are extremely many national sources, however. Exploring some of these sources makes apparent that some lead to relevant information and many do not. Exploring the entire web of possible national sources goes beyond the scope of this study. For this reason, the focus has been on European level sources. However, for the sake of estimating the feasibility of further development of a European level source on regional data, 3 example EU countries - as a case study - were searched via national sources.

2.2 Data availability and gaps

2.2.1 Data available through European level sources

Regional breakdown, for both road (passenger and freight) and rail, of transport performance per vehicle type (weight category, fuel type) or vehicle Euro-classification is not available through European level sources such as Eurostat. This may be inherent to the fact that these indicators are (nationally) registered upon distribution from the car manufacturers, not upon (local) registration. However, this imposes an important flaw on the overall regional emission knowledge. As opposed to vehicle fleet data, emission factors (both road and rail) are indeed available to a much more detailed level of vehicle type and e.g. emission category (see chapter 3). This is an important possibility for improvement.

The absence of a regional differentiation of road transport performance per road class or road type also represents an important flaw on the overall regional emission knowledge. Regional flow and fleet data per road class are only known within some countries.

There is not one central institute or organisation which is responsible for the regional data collection through all member states and which can provide the data overview. As a result, countries will have little ownership or appreciation of the need for the task of regional data collection. This results in lack of harmonisation of data collection through the EEA countries. There is an enormous amount of potential national (mainly web-based) sources that may in the end offer regional data on only one single indicator. This leads to a highly fragmented and difficult to handle set of data sources. For example, digging into only one country's data sources will lead to *tens* of universities, *tens* of specific statistics institutes, *tens* of transport companies, *tens* of trade organisations, *tens* of governmental institutions, and so on.

The problems with data availability are characterised by:
- Lack of regional disaggregation for many EEA countries' transport data.
- Lack of transport indicator disaggregation for many EEA countries' transport data.
- High diversity of data type (parameters monitored) between individual countries.

The most important underlying causes are:
- General parameter definition problems.
- Different approaches to regional breakdown.
- Different driving forces for monitoring ('easily monitorable' versus 'important' indicators).
- Typically national (not regional) character of some transport indicators.

From the scattered matrix of transport indicators on road and rail flow and fleet a set of transport indicators can be distilled that is relatively complete through all EEA member states. Table 1 presents the set of transport indicators which is found to have a high availability throughout the EEA countries and which can be collected from European level data sources. This set thus represents the level of disaggregation that can be achieved at this moment.

Besides official statistics also additional data might be available from several European Commission documents[2]. Access to these data is restricted so that the overall availability and quality could not be assessed.

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2 EUROMATRIX project, IASON project, INDICAT 2020 project, INFOSTAT project and (Eurostat) IMEG project.

Table 1 Current possible level of regional disaggregation of transport indicators based on data from European level sources.

Indicators per Region on (I) sub-country /(II) country level

Traffic Flow (Road)																																
Indicator/Country	BE	DK	GE,r9	GR	ES	FR	IE	IT	LU	NL	AT	PT	FI	SE	UK	CY	CZ	ES	HU	LV	LT	MT	PL	SK	SI	BG	RO	TR	IS	NO	LI	CH
Freight Traffic, country-to-country flow [tonne-km]	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x							
Freight Traffic [tonnes loaded/unloaded]	x	x	x		x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x		x	x	x					x		
Freight Traffic, interregional [tonnes]	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x					x		x
Freight Traffic, international [tonnes]	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x					x		x
Freight Traffic, [trucks/day]	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x																	
Freight Traffic, [km/day]	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x																	
Passenger share [# pass]	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x					x		x
Passenger share, interregional [# pass]	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x					x		x
Passenger share, international [# pass]	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x					x		x
Passenger share by origin [# trips]	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x					x		x
Passenger share in total road+rail+air [%]	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x					x		x
Passenger trips per capita, long distance	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x					x		x
Vehicle Fleet (Road)																																
Indicator/Country	BE	DK	GE,r9	GR	ES	FR	IE	IT	LU	NL	AT	PT	FI	SE	UK	CY	CZ	ES	HU	LV	LT	MT	PL	SK	SI	BG	RO	TR	IS	NO	LI	CH
All vehicles (except trailers and motorcycles)	x		x			x			x				x	x					x	x		x										
Car possession	x		x			x			x				x	x					x	x		x										
Motorcycle possession [#]	x		x			x			x				x	x					x	x		x										
Busses [#]	x		x			x			x				x	x					x	x		x										
Freight vehicles [#]	x		x			x			x				x	x					x	x		x										
Trailers and Semi-Trailers [#]	x		x			x			x				x	x					x	x	x	x										
Tractors [#]	x		x			x			x				x	x					x	x	x	x										
Special Vehicles [#]	x		x			x			x				x	x					x	x	x	x										
Total Utility Vehicles [#]	x		x			x			x				x	x					x	x	x	x										

Indicators per Region on (I) sub-country /(II) country level

Traffic Flow (Rail)																																
Indicator/Country	BE	DK	GE,r9	GR	ES	FR	IE	IT	LU	NL	AT	PT	FI	SE	UK	CY	CZ	ES	HU	LV	LT	MT	PL	SK	SI	BG	RO	TR	IS	NO	LI	CH
Freight share, interregional [tonne]	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x					x		x
Freight share, international [tonne]	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x					x		x
Passenger share, interregional [# pass]	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x					x		x
Passenger share, international [# pass]	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x					x		x
Passenger share by origin [# trips]	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x					x		x
Passenger share in total road+rail+air [%]	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x					x		x
Passenger trips per capita, long distance	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x					x		x

Vehicle Fleet (Rail)																																
Indicator/Country	BE	DK	GE,r9	GR	ES	FR	IE	IT	LU	NL	AT	PT	FI	SE	UK	CY	CZ	ES	HU	LV	LT	MT	PL	SK	SI	BG	RO	TR	IS	NO	LI	CH
Diesel trains																																
Electric trains																																
Freight trains																																
Passenger trains																																

Traffic Flow (Road plus Rail)																																
Indicator/Country	BE	DK	GE,r9	GR	ES	FR	IE	IT	LU	NL	AT	PT	FI	SE	UK	CY	CZ	ES	HU	LV	LT	MT	PL	SK	SI	BG	RO	TR	IS	NO	LI	CH
Passenger trips per capita, long distance	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x					x		x

The most important missing indicators in Table 1 are:

- Freight flow (road) (vehicle-km).
- Freight flow (road) (tonne-km).
- Freight flow (rail) (vehicle-km).
- Freight flow (rail) (tonne-km).
- Passenger flow (road) (passenger-km).
- Passenger flow (rail) (passenger-km).

2.3 Data available through national sources

Data searches in national sources in many cases provided data at a more detailed level. For reasons that are explained above, it was not possible within the scope of this study to dig out all possible national data sources. In order to get a flavour of additional data availability from within national sources, however, a survey was exercised for 3 EU countries. The example, that is worked out in Table 2 below, demonstrates that a lot of data is nationally maintained but not shared within commonly used European statistics institutions. From this example it can be concluded that a significant level of transport data disaggregation is fairly likely feasible if nationally kept data was to be shared on a European level.

Table 2 Examples of regionally disaggregated transport indicators available from national level sources. Grey fields represent data which is available via individual country's sources but which is not available via European sources

Indicators per Region on (I) sub-country /(II) country level

Traffic Flow (Road) *Indicator/Country*	Belgium	Denmark	Netherlands
Avarage traffic Intensity (# vehicles)			x
Congestion intensity			x
Total road traffic flow [vehicle-km]	x		
Total road traffic flow [#vehicles]		x	
Freight Traffic Intensity [tonne-km/km road]	x		
Freight Traffic, country-to-country flow [tonne-km]	x	x	x
Freight Traffic [tonnes loaded/unloaded]	x	x	
Freight Traffic [tonne-km]	x	x	
Freight Traffic, interregional [tonnes]	x	x	x
Freight Traffic, international [tonnes]	x	x	x
Freight Traffic, [trucks/day]	x	x	x
Freight Traffic, [km/day]	x	x	x
Passenger Share [km]			x
Passenger share [# pass]	x	x	x
Passenger share, interregional [# pass]	x	x	x
Passenger share, international [# pass]	x	x	x
Passenger share by origin [# trips]	x	x	x
Passenger share in total road+rail+air [%]	x	x	x
Passenger trips per capita, long distance	x	x	x
(1a) Car [pass-km]	x		x
(1b) Car differentiated to road type [pass-km]	x		
(1c) Car differentiated to road type [vehicle-km]	x	x	
(1d) Car load differentiated to road type [#pass]	x		
(2a) Motorcycle [pass-km] = [vehicle-km]	x		x
(2b) Motorcycle, to road type [pass-km = vehicle-km]	x		
(3) Moped			x
(4a) Bus [pass-km]	x		x
Vehicle Fleet (Road) *Indicator/Country*	Belgium	Denmark	Netherlands
All vehicles (except trailers and motorcycles)	x		
Car possession	x	x	x
Motorcycle possession [#]	x		x
Moped possession			x
Motorcycle + moped/scooter			x
Diesel cars [% of total car fleet]	x		
Busses [#]	x		x
Freight vehicles:	x		x
(1) Vans/light commercial vehicles			x
(2) Lorries	x		x
(5) All mid plus heavy weight	x		
Trailers and Semi-Trailers [#]	x		x
Tractors [#]	x		
Special Vehicles [#]	x		
Total Utility Vehicles [#]	x		
Total vans, lorries, trailers, government fleet, busses, tractors			x
Passenger cars building years / age			x

Indicators per Region on (I) sub-country /(II) country level

Traffic Flow (Rail)			
Indicator/Country	Belgium	Denmark	Netherlands
Freight share [tonne-km]	x	x	x
Freight share [tonne]	x		
Freight share, interregional [tonne]	x	x	x
Freight share, international [tonne]	x	x	x
Passenger share [pass-km]	x		
Passenger share [# pass]		x	
Passenger share, interregional [# pass]	x	x	x
Passenger share, international [# pass]	x	x	x
Passenger share by origin [# trips]	x	x	x
Passenger share in total road+rail+air [%]	x	x	x
Passenger trips per capita, long distance	x	x	x

Vehicle Fleet (Rail)			
Indicator/Country	Belgium	Denmark	Netherlands
Diesel trains		x	
Electric trains		x	
Freight trains		x	
Passenger trains		x	

Traffic Flow (Road plus Rail)			
Indicator/Country	Belgium	Denmark	Netherlands
Inland freight (r1,r2) [tonne-km/GDP]	x	x	x
Passenger transport (r3,r4,r5) [passenger-km/GDP]	x	x	x
Passenger trips per capita, long distance	x	x	x

2.3.1 Other possibly useful data sources

ETIS

One interesting data source in particular, ETIS[3], deserves to be mentioned here, for it covers many transport indicators as well as emissions, for NUTS2 and NUTS3 regions in the EU25, Norway and Switzerland. The ETIS (European Transport policy Information System) project was performed on behalf of DG TREN, under the 'Competitive and Sustainable Growth' Programme. The ETIS project has developed a database tool for assessment and monitoring of transport performance indicators and impacts of road, rail, waterway and air transport in relation to the Trans-European transport Network (TEN). For road and rail the database offers emission assessment outputs (e.g. NO_x-, PM- or CO_2-emissions in g/km^2) on a regional scale (NUTS3 regions)[4], all in a regional breakdown. However, the goal of ETIS was to assess the impacts of TEN and Pan-European corridors for international transport and other long-distance flows. For that reason, local short distance transport was *not* included in the emission calculations. This implies that *true* coverage of transport emissions per region is not available from ETIS. For example, the ETIS method can camouflage significant transport volumes in regions that have a transport emphasis on distribution *within* that region. Furthermore, the entire contribution of local and regional commuting transport (work, school, leisure) is excluded. For the EEA goal of our current investigation, the ETIS emission mapping is therefore not complete. However, it could provide a good high level understanding of regional differences in emission load.

The ETIS methodology for estimating transport performance indicators, energy consumption and emissions is described in project reports available from the ETIS-website[5]. The project is a follow up of COMMUTE and largely follows the same methodology. For the road and rail network on each link vehicle kilometres are multiplied by emission factors derived from COMMUTE, MEET and the HBEFA Handbook Emission Factors[6]. For road vehicles the emission factor methodology is stated to be consistent with COPERT[6]. Transport data for the TEN network are derived through network modelling, using origin/destination (O/D) matrices as the most important input. These O/D matrices are derived from various national and other data sources. Resulting traffic volumes have been calibrated against statistics including UN-ECE road counts. The modelling methodology has been developed in TEN-STAC[7]. Due to more detailed input data for freight transport the transport performance data for freight transport are more accurate than for passenger transport[8].

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3 http://www.etis-eu.org/index.html.

4 ETIS Statistical handbook, NEA Transport Research and Training BV, August 2005, ISBN 90-8665-001-5.

5 e.g. D5 Annex report WP 8: ETIS Database methodology development and database user manual – External effects V3.0, available from: http://www.etis-eu.org/library/reports.html.

6 For more information on these emission factor models see chapter 3.

7 http://www.nea.nl/ten-stac.

8 Personal communication with Mr. M. Chen (currently at TNO), former project leader of the ETIS Reference database development at NEA Transport research and training BV, the Netherlands.

If local, short distance transport could be included in the methodology then the ETIS database could be a starting point for regional inventories of transport emissions. For the purpose of ETIS it has been proved that the required data are available through statistics and additional modelling.

New developments
Another (future) source that should not stay unmentioned here, is a European database of vehicle stock for the calculation and forecast of pollutant and greenhouse gases emissions with TREMOVE and COPERT. It is a future source and could be highly valuable. The European Commission, Directorate-General Environment dispatched a contract notice (dated 12.5.2006) on a tender for the development of this database. Objective is to build a consistent and accurate European-wide database providing detailed information on the stock of vehicles at country or regional level and as a minimum for each year of the period 2000-2005, covering the requirements of TREMOVE, TERM and COPERT. The contractor is also to define a methodology for the further regular update of the database.

The scope of the database includes EU25, Rumania, Bulgaria, Croatia, Turkey, Switzerland and Norway. The scope of the database is not limited to road vehicles but includes the stock of locomotives, inland ships and maritime vessels by type of traction and power classes, and aeroplanes, as well as non-road mobile machinery.

2.3.2 Conclusion regarding data availability

In conclusion, it is found that throughout the many individual countries, a very wide variety of transport indicator monitoring is maintained. However, there is no such thing as a default set of indicators to be monitored, and this results in a scattered EEA-wide data availability matrix. Gaps in regional data availability occur for all indicators. In general, data availability is higher for road than for rail transport. A reason for this may be the fact that rail exploitation is a national issue and many rail companies are owned by governments. This typically leads to data maintenance on a national instead of a regional level.

2.4 Problems with data definition

As a result of individual countries taking individual approaches to monitoring and statistics, definition problems are inevitable. The definition problems encountered in this review are three-fold.

2.5 Definition consistency

When definitions are provided, they appear to be inconsistent throughout individual sources. This means data from different sources can carry the same labels but have in fact different meanings, implying the risk of false comparison of data. This can be illustrated by the label 'Van'. The van has been defined in several ways, a.o.:

- 4-wheel vehicle with maximum weight (including load) of 3,500 kg; many trucks and special utility vehicles (like fire brigade vehicles) fall in the same definition category while they have other emission factors then vans.
- 3- or 4-wheel vehicle with maximum weight (including load) of 3,500 kg; governmental cleaning vehicle fleet also fit this definition, but sometimes they are put in a separate category.
- Some countries include vans under the label of passenger cars.

Another illustration is the label 'Motor cycle', which goes by a range of definitions:
- Motor cycle.
- Motor cycle + moped.
- Motor cycle + moped + scooter.
- Motor cycle + moped + scooter + motorised invalid car.

Definition clarity
Not all data sources provide the definitions they use. Therefore, it is often not possible to determine whether or not definitions are consistent.

Allocation problems
Transport flow data is often based on movements on national(/regional) territory, regardless of the nationality (or region of registration) of the vehicle. From an emission inventory perspective, this is very useful. However, it is unclear in most cases if this method is indeed used or instead nationality (or region of registration) of the vehicle is used as basis.

Determining the number of passenger cars (car possession) per geographic unit is often based on the place of residence as per registration of the number plate. The presence of large or many lease companies in a certain region can affect the number of passenger cars allocated to that region.

2.5.1 Different approaches to regional breakdown

A challenge in comparing data is the difference in approach to regional breakdown that the individual member states use. Even in a reliable and steady statistics source like Eurostat, differences are encountered between different member states. For instance, if we look at Eurostat's regional transport data on car possession and take two arbitrary example member states. (1) For Denmark, we find no data at all. (2) For Germany, we find (2i) a regional breakdown and (2ii) in addition, these regions are further split into sub-regions. Looking into the German regions however, not all regions are completed with the sub-regional data. So, even within one data source and within one country, the availability of data is not robust. This is a result of the fact that Eurostat retrieves their data from the individual countries, which all have their own monitoring, registration and reporting mechanisms.

Another approach some countries take is not to look into actual regional transport (i.e. including short-distance transport) but long-distance transport through regions. The latter method can camouflage significant transport volumes in regions that have a transport emphasis on distribution *within* that region.

2.6 Suggestions for Improvement

The suggested path forward to improving the state of data availability and filling existing gaps would be two-fold. A suggested first step, is an in depth review of the availability and reliability of regional transport data within national sources. Ideally, this would imply involvement of all European national statistics institutes and Eurostat. This in-depth review of data availability could be combined with efforts to define a common methodology for collecting, storing and sharing regionally specific transport performance data and could e.g. be carried out in the context of an EU-funded (Framework) project.

The actual effort of filling the gaps and implementation of a Europe-wide database of regionally specific transport indicators would make the second step. The main national statistics institutes should cooperate in a joint effort with Eurostat, with the shared goal of adequately collecting all relevant regional transport data into one central source. Via this organisational structure, many European statistics expert institutes will be involved in developing one common product, in which they all are stakeholders.

The paragraph below gives some suggestions for the approach that could be taken in such EU implementation project.

2.6.1 Straightforward approach through methodological improvement

The suggested path forward to improving the state of data availability and filling existing gaps, contains the following main steps:

1. Enrolling a notification to all EEA member states, declaring the importance and the goal of a common approach to geographical disaggregation of transport data.
2. Select one statistics institute, such as Eurostat, to facilitate and be responsible for this process throughout all the EEA member states.
3. Outlining a general and high-level matrix of transport indicator disaggregation, matching existing disaggregation of emission factors.
4. Outlining a general and high-level matrix of regional disaggregation (NUTS2/NUTS3).
5. Investigate build-up of published data (regional data might be hidden available, as published national data may be the sum of regional data).

Several works by the Commission give insight of good methods for data collection in general and questionnaires set-up in particular[9] and could serve as guidelines for this work.

Furthermore, an alternative approach in collecting transport data for important indicators that are not available as such (i.e. in a direct way) could be through modelling or deviation.

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9 For example: European Commission, Road freight transport methodology, Volume 1, Reference manual for the implementation of Council Regulation No 1172/98 on statistics on the carriage of goods by road, 2005, ISBN 92-894-9880-3.

2.6.2 Alternative approach through modelling and derivation

In addition to plain data collection, a combined approach modelling and derivation or estimation of relevant variables was taken by the ETIS project for DG TREN.

Modelling
DG TREN has ownership of a European transport models project (TRANS-TOOLS), which a.o. contains prognoses on transport indicators, and would therefore make a good starting point. TRANS-TOOLS is based a.o. on the SCENES model (passenger transport, the interaction of local and long distance traffic, and intermodal transport), the VACLAV transport network (transport assignment) and NEAC (description of freight transport.

Derivation
Many transport indicators are related to each other, making derivations a suitable method for determining or approximating indicators that are not available in a direct way. E.g. national freight flows can be split up into regional freight flows by looking into the dynamics of freight terminals. As a next step, using destination terminals, route networks (waterways, roads, railways) and transport modes patterns (i.e. typical or estimated distribution load over maritime shipping, inland shipping, road and rail modes), can lead to an estimate of regional tonne-kilometres per mode.

2.7 Summary

Based on a review of data sources at the European level the current state of regional (sub-country) data availability on road and rail transport flow and vehicle fleet for EEA member states, is assessed as overall - moderate to poor with regard to the variables that are most relevant for emission inventories. For a small group of other possibly useful transport indicators, however, the data availability is assessed as fairly good. For many other indicators, data on a regional level is available only for a few countries. In general, data availability is higher for road transport than for rail transport.

A review of data availability through a limited number of national data sources shows that information on the relevant regional transport performance indicators may be available in national statistics, but is apparently not shared through international statistical databases.

3 Emission factors for regional emission inventories of road and rail transport

3.1 Introduction

This chapter explores the need and possibilities for regional differentiation or disaggregation of emission factors as provided by existing emission models. Besides the COPERT emission factor handbook, as managed by EEA, also some other models will be reviewed. One reason for this is that national emission inventories are not for all European countries based on COPERT. Another reason is that other models might provide other opportunities for regional differentiation.

3.2 Road traffic

The methodology for calculating road transport emissions as part of national emission inventories is described in the EMEP-CORINAIR Emission Inventory Guidebook[10]. The guidebook presents two alternative calculation methods. A simplified method is based on multiplying the annual fuel consumption per vehicle category with bulk emission factors expressed in g/kg fuel. A more detailed and preferred methodology is based on transport performance (vehicle kilometres driven) and emission factors expressed in g/km. This method is made operational in the European road vehicle emission factor model COPERT III[11]. Both methods can in principle be used on a national as well as a regional level.

Alternatively overall national or regional emissions can be determined by means of multiplying transport performance indicators in terms of passenger kilometres or tonne-kilometres per mode with emission factors expressed as gram per pkm or tonne-km. Determining the latter, however, requires implicit or explicit assumptions about all aspects that determine the emissions expressed per vehicle kilometre or per unit of energy used.

Regardless of the size or definition of the ‘region’, regional emissions from road traffic are generally determined by the following main factors:
- Regional transport performance expressed in vehicle kilometres travelled per category of vehicles on different road types.
- Emissions in gram per vehicle kilometre per category of vehicles and per road type.

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10 Emission Inventory Guidebook 2005, Group 7: Road transport, EEA-website: http://reports.eea.europa.eu/EMEPCORINAIR4/en/page016.html.

11 *COPERT III: Computer programme to calculate emissions from road transport, Methodology and emission factors* (version 2.1), L. Ntziachristos et al., EEA, November 2000.

At both levels regional variations occur. Differentiating national road transport and emission statistics into regional inventories requires on the one hand the possibility to obtain regional statistics on fleet compositions and vehicle use, and on the other hand could involve regional differentiation of emission factors. The latter is generally determined by:

- Regional differences in the characteristics of vehicles within a given vehicle class.
- Regional differentiation of emission factors that are affected by climate (cold start emissions, indirect energy use and exhaust emissions resulting from the use of air-conditioning systems, evaporative emissions, etc.).
- Regional differences in traffic characteristics (e.g. average speed and driving dynamics due to road conditions, congestion, etc.).
- Possible other aspects such as level of maintenance, regional variations in occupancy factors of passenger cars or buses or loading factors for HD vehicles, fuel quality, etc.

In the sections below the impact of regional variations in the above aspects is qualitatively discussed. It will be indicated to what extent various aspects are taken into account in COPERT III or COPERT 4. As no detailed documentation is available yet for COPERT 4 for some aspects only a reference to COPERT III will be made. The website on COPERT 4 mentions that the presently available test version still used the COPERT III methodology, but that various methodological changes are in preparation.

Also some other emission factor models will be discussed, notably:

- German / Swiss / Austrian Handbook Emission Factors[12].
- ARTEMIS[13].
- VERSIT+[14].

The latter two are the most recently developed models. A brief description of these models is provided in Annex A.

3.2.1 Regional fleet composition and vehicle use

Regional fleet composition and vehicle use may differ significantly from the national average fleet composition and use depending on e.g. the economic situation in a region, the level of urbanisation, and e.g. cultural differences influencing consumer choice.

The influence of regional fleet composition in terms of vehicle types (vehicle type, fuel type, size or mass or cc-class, emission legislation class, age) is best accounted for on the basis of disaggregated transport performance data (in vehicle kilometres) per vehicle type combined with specific emission factors for each vehicle type. If such a breakdown of transport data is not available then a

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12 *Handbuch Emissionsfaktoren des Straßenverkehrs*, HBEFA 2.1, UBA Berlin / BUWAL Bern / UBA Wien, http://www.hbefa.net/ or http://www.umweltbundesamt.at/umweltschutz/verkehr/abgase/hbefa/.

13 ARTEMIS: Assessment of Road Transport Emission Models and Inventory Systems, http://www.trl.co.uk/artemis/index.htm.

14 *A New Modelling Approach for Road Traffic Emissions: VERSIT+ LD – Background and Methodology*, R. Smit et al., TNO Automotive, the Netherlands, TNO report nr. 06.OR.PT.016.1/RS, July 2006.

simplified approach can be used based on estimating an average emission factor for an aggregated group of vehicle types based on the fleet composition (in number of vehicles) which is then multiplied by the transport performance of the complete group of vehicle types. In general transport performance data will be available for main classes of vehicles (passenger cars, trucks, buses, etc.) but for the various sub-classes within these main classes such data are not always available. Fleet statistics generally provide numbers of vehicles in various detailed classes (categorised by age or emissions legislation class and a parameter indicating vehicle size (e.g. mass or GVW, engine power or cylinder content), but transport performance data are generally not differentiated to the same level of detail. Transport data are generally derived from surveys (e.g. questionnaires or log books filled out by a sample of vehicle users) or from on-road measurements (e.g. using detection loops in the road that sometimes can distinguish between small and large vehicles).

It is known that the fleet composition is very different on different road types. On urban roads the share of older vehicles and of petrol vehicles is generally higher than the national average, while on highways the share of new and especially diesel vehicles is higher. Local variations may however be significant. Especially during rush hours the fleet on highways near cities or in highly urbanised areas is largely resulting from regional commuter traffic with a fleet composition that is closer to a typical urban fleet composition than to that of a rurally located highway section. Especially variations in composition with respect to age and fuel type have a significant influence on overall emissions. Euro 3 and 4 passenger cars on petrol emit roughly a factor of 20 less than Euro 0 petrol vehicles on most emission components, while e.g. Euro 3 passenger cars on diesel emit a factor of 10 more NO_x and PM than comparable petrol vehicles. In some urban areas a large share of mopeds with two-stroke engines also has a significant effect on local and regional emissions. Although it is clear that the impacts of variations in fleet composition on local or regional emissions is quite significant, little or no quantitative data are available on local or regional fleet composition (or number of vehicle kilometres driven per vehicle category (defined by vehicle type, fuel type, size or mass or cc-class, and age)). For this reason this aspect is usually not appropriately taken into account in local or regional emission inventories or air quality studies.

The overall emission modelling in COPERT III and COPERT 4 allows the use of regionally specific fleet compositions, to be provided as input by the user. Users can even include new vehicle types that may be typical for a region, but in that case the user also has to provide emission factors for these vehicles.

3.2.2 Regional differences in the characteristics of vehicles within a given vehicle class

The possible size of regional variations of the characteristics of vehicles within a given vehicle class and its impact on emission factors depends on the aggregation level used for the categorisation of vehicle classes. If the fleet is e.g. only categorised in terms of passenger cars, vans, trucks and buses, then the average value as well as distribution for parameters such as vehicle age, size, weight, cylinder content, engine power, etc. may differ strongly between countries and regions. In fleet statistics, however, vehicle categories usually also include a categorisation according to age and a parameter indicating size or power. Within each detailed class still regional variations may occur, but these can be considered negligible for the level of regional differentiation that is considered in this document.

3.2.3 Regional differentiation of emission factors that are affected by climate

Emission factor models are usually based on a detailed modelling of the so called 'hot running' emissions. These are the emissions produced by a vehicle with a warm engine. Hot running emissions are then corrected to include real-world effects such as:

- Cold start emissions, including cranking emissions at start-up and the additional emissions produced in the first minutes of driving before engine and aftertreatment system have reached normal operating temperatures[15].
- Indirect energy use and exhaust emissions resulting from the use of air-conditioning systems.
- Evaporative emissions.

Cold start emissions are generally influenced by the ambient temperature, and at a more detailed level by the driving characteristics in the first kilometres after start-up and the time between shut-down and start-up of the engine. The latter aspect is generally not taken into account. The impact of ambient temperature can be taken into account by using a yearly average ambient temperature or by accounting for seasonal variations. In COPERT III the $\mathbf{e^{cold}/e^{hot}}$ cold start correction factor is a function of ambient temperature.

The use of mobile air conditioning systems (MACS) results in an additional load on the engine which I turn causes increased fuel consumption and generally also increased emissions. The latter effects may be quite non-linear. Under high load conditions, e.g. during accelerations or hill climbing, the extra engine load may force the engine into a part of its engine map where fuel enrichment is applied to limit the temperature of the engine. The impacts of MACS are determined by the amount of vehicles in the fleet that is equipped with MACS, technical characteristics of the MACS and the amount of time that the MACS is used. The latter is obviously influenced by regional variations in climatic conditions.

15 For some components emissions during the cold start phase may be lower than during warm operation for a given vehicle type.

Evaporative emissions are strongly influenced by ambient temperature. COPERT III calculates evaporative emissions based on two different methodologies: the CORINAIR method and a method based on research work by CONCAWE. Both methods provide formulas for diurnal losses, hot and warm soak emissions and hot and warm running losses that include monthly ambient temperature and temperature variation as input parameters. The CORINAIR method is know to overestimate hot soak emissions, especially for modern (Euro 2 and later) vehicles. The user is allowed to select one of the methods for his calculations.

3.2.4 Regional differences in traffic characteristics

The road type influences emissions through its average traffic characteristics, characterized by e.g. average speed and parameters describing the dynamics of driving. Road types may be defined at a rather aggregate level ('urban', 'rural', 'highway'), but may also be differentiated at a more detailed level, e.g. in relation to number of lanes, allowed maximum speed, curvature, gradient, etc. For a given road type driving dynamics is influenced by traffic intensity and the level of congestion, with congestion generally resulting in lower average speeds and higher dynamics.

Traffic intensity and levels of congestion show significant regional variations. Driving dynamics and the resulting local vehicle emissions may be influenced by traffic measures. Measures that promote a smooth flow of traffic at moderate speeds generally result in lower emissions and are implemented in various locations as a means to improve local air quality. Depending on the regional scale under consideration and the extent to which these measures are applied their impact may also affect overall regional emissions. In general, however, the impact of such local effects on overall emissions at a regional or national level is quite limited. E.g. for driving in highly congested the emissions expressed in g/km may be factors higher than the emissions under free flow circumstances, but the amount of kilometres driven in traffic jams is generally only one or a few percent of the overall transport performance (although the time spent in traffic jams is a higher share of the overall time driven).

Dealing with this kind of variations requires that the amount of kilometres driven by different vehicle categories on different road types under different traffic conditions is known.

Effects of traffic characteristics are included in COPERT through the selection of road type and variation of the parameter average speed. Experience from the development of the TNO model VERSIT+, however, has shown that modelling based on average speed alone can not accurately describe emission variations in relation to the level of congestion or e.g. traffic measures influencing traffic flow[14]. VERSIT+ models hot-running emissions as a function of a large number of variables that characterise the dynamics of a driving pattern that is selected to be representative for the situation for which emissions are calculated. The EU-funded ARTEMIS-project has developed emission factors for a wide range of detailed road type definitions (in terms of number of lanes allowed maximum speed, curvature, gradient, etc.).

Other relevant information on traffic characteristics includes the number of cold starts per km driven, which is related to the average trip distance.

3.2.5 Other aspects

Other aspects that may cause regional variations in emission factors include:
- Level of vehicle maintenance.
- Regional differences in driving styles.
- Regional variations in occupancy factors of passenger cars or buses.
- Regional variations in loading factors for LD commercial vehicles and trucks.
- Regional variations in fuel quality.

The impact of maintenance on emissions is not generally included in emission factor modelling due to limited available data.

Driving styles are known to be different in different regions of Europe. Quantifying these effects is possible in some emission factor models. Obtaining regional information on this aspect as input for the emission factor model, however, is more difficult. Currently some quantitative information in the form of driving cycles for different driving styles and correction factors compared to 'normal driving' are available nationally[16], but information on the shares of driving styles in Europe, at the national or at a regional level is not available.

In models that connect exhaust emissions to propulsion power it is often possible to vary loading factors. It is, however, usually considered sufficient to work with average occupancy or loading factors.

Fuel composition and quality have an influence on emissions. Throughout Europe fuel composition varies. E.g. emissions of lead and SO_2 directly correlate with the use of leaded petrol resp. the sulphur content of the fuel, but fuel composition (incl. the use of various additives) also influences regulated emissions (HC, CO, NO_x and PM). Also the availability of alternative fuels varies between countries and regions. Alternative fuels include LPG, CNG and various biofuels such as E85 (85% ethanol / 15% petrol) or biodiesel (esterified vegetable oils). For LPG and CNG vehicles reasonably reliable emission factors are available from different sources. The amount of information available on emissions of vehicles on biofuels does not yet allow the calculation of statistically significant emission factors.

[16] E.g. in the Dutch national methodology for modelling road vehicle emissions. See: http://www.cbs.nl/NR/rdonlyres/E235AABD-7E62-4883-A337-5164BE8E08AB/0/emissiesmobielebronnen.pdf (in Dutch).

3.2.6 Conclusions on emission factors for road transport

Emission factors such as available through the COPERT methodology in principle enable the modelling of regional variations with respect to:

- Fleet composition and transport performance per vehicle type.
- Ambient temperatures (and their impact on cold start emissions and evaporative emissions).

From the documentation it is not clear whether emissions related to airco use and regional variations thereof are taken into account in COPERT. Effects of traffic characteristics are included in COPERT through the selection of road type and variation of the variable ‘average speed’. Experience from the development of VERSIT+, however, has shown that modelling based on average speed alone can not accurately describe emission variations in relation to the level of congestion, driving styles or e.g. traffic measures influencing traffic flow. Given that COPERT is the prescribed model to be used for EU emission inventories the functionality of COPERT with regard to modelling variations in traffic characteristics could be used in first instance, but for the longer term the use of a new model or an update of COPERT (possibly on the basis of new models that are more advanced with regard to this aspect) would seem advisable.

Overall it can be concluded that the possibilities to model regional differences in road vehicle emissions are more limited by the availability of regional statistics on road vehicle fleet composition and transport performance on various road types than on the limitations of the COPERT emission factors model or other (nationally) available models.

3.3 Rail Traffic

3.3.1 Introduction

The methodology for calculating rail transport emissions as part of national emission inventories is described in the EMEP-CORINAIR Emission Inventory Guidebook[17]. The guidebook presents two alternative calculation methods. A simplified method is based on multiplying the annual fuel consumption per vehicle category with bulk emission factors expressed in g/kg fuel. A more detailed methodology is based on usage statistics expressed in operating hours, emission factors expressed in g/kWh delivered engine power and information on installed engine power and typical load factors:

$$E = N \times HRS \times HP \times LF \times EF_i$$

[17] Emission Inventory Guidebook 2005, Group 8: Other mobile sources and machinery, EEA-website: http://reports.eea.europa.eu/EMEPCORINAIR4/en/page017.html.

with:

E	=	mass of pollutant i during inventory period.
N	=	source population (units).
HRS	=	annual hours of use (h).
HP	=	average rated engine power (kW).
LF	=	typical load factor.
EF_i	=	average emission of pollutant i per unit of use (g/kWh).

The parameters N, HRS, HP, LF and EF_i can be differentiated according to vehicle class (e.g. specified by vehicle type or engine output class), vehicle age or emission legislation category. A discussion of these and alternative methods as well as application of these methods to estimate emissions from rail transport in various European countries is given in the MEET report 'Estimating Emissions from Railway Traffic'[18]. The main method used in that report is based on multiplying emission factors in g/kWh with an estimate of the energy consumption per train type based on the energy consumption per tonne-km combined with the average weight in tonne per seat, the load factor of the train in passengers per seat and the amount of passenger-km transported by a given train type in the time frame under consideration.

The above method can be used to estimate emissions from trains driven by diesel engines. For electric trains the (indirect) emissions are in principle calculated by multiplying the electricity consumption in kWh with emission factors for electricity production in g/kWh. Methodologies for the latter are also given in the EMEP-CORINAIR Emission Inventory Guidebook[19]. In national emission inventories, however, emissions from electric trains are often included in the assessment of emissions from electricity production and not in the inventory of transport emissions.

Regardless of the size or definition of the 'region', regional emissions from rail traffic are generally determined by the following main factors:

- Regional transport performance, in terms of passenger kilometres travelled, composition of the fleet and share of various train types in the total transport performance, either expressed in vehicle kilometres driven or energy consumed per category of vehicles.
- Emissions in gram per vehicle kilometre or gram per kWh per category of vehicles.

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18 *Estimating Emissions from Railway Traffic*, M.W. Jørgensen and S.C. Sorenson, Report for the project MEET (Methodologies for Estimating air pollutant Emissions from Transport), report nr. ET-EO-97-03, Technical University of Denmark, July 1997.

19 Emission Inventory Guidebook 2005, Group 1: Combustion in energy and transformation industries, EEA-website: http://reports.eea.europa.eu/EMEPCORINAIR4/en/page010.html.

At both levels regional variations occur. Similar to the case for road vehicles, differentiating national rail transport and emission statistics into regional inventories requires on the one hand the possibility to obtain regional statistics on fleet compositions and vehicle use, and on the other hand could involve regional differentiation of emission factors. For diesel trains the latter would be determined by:

- Regional differences in the characteristics of vehicles within a given vehicle class.
- Regional differentiation of emission factors that are affected by climate (e.g. cold start emissions, indirect energy use and exhaust emissions resulting from the use of heating or cooling systems).
- Regional differences in vehicle use characteristics (e.g. average speed and driving dynamics, number of stops, regional variations in occupancy factors of passenger trains or loading factors / train lengths of freight trains) e.g. expressed through the load factor.
- Possible other aspects such as level of maintenance, fuel quality, etc.

Regional inventories can be based on aggregated information on the above parameters collected at the regional level or could be based on assessments of emissions per individual rail section or yard. An example of the latter is the Finnish RAILI model[20] which is also used for the national emission inventory in Finland. For e.g. the Dutch national emission inventory emissions from rail transport using diesel traction are based on the simplified approach based on multiplying the annual fuel consumption per vehicle category with bulk emission factors expressed in g/kg fuel[21].

Regional fleet composition and vehicle use

Fleet composition in terms of train / locomotive types (vehicle type, power class, emission legislation class, age) and the use of various train / locomotive types will generally differ per region depending on the level of urbanisation and industrialisation and the available infrastructure.

The Emission Inventory Guidebook[10] distinguishes three types of trains:

- Shunting locs (for use in yards).
- Rail cars (mainly for urban and regional passenger trains).
- Locomotives (for longer distance passenger trains and freight trains).

Other sources use a more detailed categorisation, e.g. distinguishing local passenger trains, regional and inter-regional passenger trains, high-speed passenger trains and one ore more types of fright trains.

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[20] RAILI 2004, VTT Finland, http://lipasto.vtt.fi/lipastoe/railie/index.htm.

[21] Klein, J., et al. (2004). *Methoden voor de berekening van de emissies door mobiele bronnen in Nederland t.b.v. Emissiemonitor, jaarcijfers 2001 en ramingen 2002*. Rapportagereeks MilieuMonitor 13. Taakgroep Verkeer en Vervoer, Emissieregistratie-RIVM, Bilthoven, http://www.cbs.nl/NR/rdonlyres/E235AABD-7E62-4883-A337-5164BE8E08AB/0/emissiesmobielebronnen.pdf.

Similar to the case of road transport, the influence of regional fleet composition is best accounted for on the basis of disaggregated transport performance data (in pkm / tonne-km, vehicle kilometres or fuel and electricity use) per vehicle type combined with specific emission factors for each vehicle type. If such a breakdown of transport data is not available then a simplified approach can be used based on estimating an average emission factor for an aggregated group of vehicle types based on the fleet composition (in number of vehicles) which is then multiplied by the transport performance of the complete group of vehicle types.

3.3.2 Regional differences in the characteristics of vehicles within a given vehicle class

Emission models for rail usually have a rather aggregated categorisation of vehicle classes. As rail vehicles are often tailor designed for the user (national or regional rail operators), large variations in vehicle characteristics may exist between countries and regions. For passenger trains e.g. variations will exist in train weight and length, the number of seats per unit length or unit mass, resistance factors and frontal area, engine power, etc. For freight trains differences between locomotives may be smaller than e.g. for passenger rail cars, but strong differences may occur in the type of rail wagons that is used, and in the length and loading factor of trains (related e.g. to the type of goods transported).

3.3.3 Regional differentiation of emission factors that are affected by climate

Emission factors for HD diesel engines as used in trains are usually derived from steady state engine tests carried out at a standardised temperature. Information on emissions as a function of ambient temperatures is not readily available. Cold start emissions are generally low for diesel engines and furthermore diesel engines in trains are usually only started once or e few times per day. Regional variations are expected to have a negligible effect. Evaporative emissions are not relevant for diesel engines.

Climatic variations may cause regional variations in the indirect energy use and exhaust emissions resulting from the use of heating or cooling systems. In the available literature this aspect of energy use and emissions is not considered. For inventories based on fuel consumption times an emission factor per unit fuel this aspect is implicitly included.

3.3.4 Regional differences in vehicle use characteristics

When fuel consumption is not known from statistics at the regional level it can be estimated using models describing the energy consumption of trains as a function of various use characteristics (see e.g. the MEET report 'Estimating Emissions from Railway Traffic'[18]).

The average speed of trains varies as a function of the maximum speed of the train and the distance between stops. The number of stops strongly influences the required propulsion energy (albeit to a lesser extent for modern electric trains with regenerative braking). The extent to which the effect of variations in usage characteristics on emissions can be assessed depends on the level of sophistication of the models that are used to estimate energy consumption and emission factors. This level of sophistication in turn strongly depends on data availability. As shown in the MEET report 'Estimating Emissions from Railway Traffic'[18] for some specific train types sufficient data are available to allow detailed modeling. This, however, will not generally be the case.

Information on the impact of transient engine operation on emissions will generally not be available for HD traction engines as used in trains. For train applications, however, this is not considered a problem as the engine operation is much less transient than e.g. in truck applications.

3.3.5 Possible other aspects

The impact of maintenance on emissions is not included in emission factor modelling due to limited available data.

Fuel composition and quality have an influence on emissions. Throughout Europe fuel composition varies. Emissions of SO_2 directly correlate with the sulphur content of the fuel, and can thus be calculated on the basis of fuel consumption.

3.3.6 Evaluation of the ARTEMIS-model

Within ARTEMIS the Technical University of Denmark, which was also responsible for the MEET rail emissions model[18], has developed a new methodology and model for rail emissions[22]. A brief description of the model and its structure is provided in Annex B.

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[22] ARTEMIS WP700 *Emission estimating methodology for rail transport*, http://www.trl.co.uk/artemis/index.htm, *Simulation of Energy Consumption and Emissions from Rail Transport*, S.C. Sorensen et al., WP 700 final report, Feb. 2005, *Simulation of Energy Consumption and Emissions from Rail Transport - Software Package User's Manual*, T.M. Cordeiro et al., Feb. 2005.

The core of the model calculates energy consumption and emissions for a given train type on a specific railway line (section between two stations). The model discerns 5 different train types (HST / Inter City / Regional / Urban / Freight). Trains are furthermore specified by the vehicle type (HST / locomotive / railcar) and the traction type (electric / diesel). The model allows various levels of regional differentiation:

- Because emissions are calculated per railway line or segment, regional emissions can be calculated by adding all emission from railway segments in a given region.
- Regional differences in train characteristics can be specified by the user.
- Emission factors can be modified by the user to represent specific diesel trains or regionally specific characteristics of electricity generation. In this process also effects of e.g. fuel quality and ambient conditions can be taken into account, provided that relevant information is available.
- Regional differences in driving dynamics can be modelled by specifying railway line specific or region specific VA-matrices.
- Regional differences in traffic intensities, occupancy factors can be specified by the user.

Calculating regional emissions from rail transport in this way requires the availability and input into the model of region specific data as listed above and may also require some modifications to be made to the model software.

The available Excel spreadsheet model in its present state of development is still rudimentary, and seems to serve more as a proof of concept then as a final tool. It does contain a database with railway lines per country (consistent with TRENDS) with general characteristics of these lines as well as the number of trains and passengers (separated in long distance and local) per day. The model, however, does not contain information on the shares of various train types that run on these railway lines. Furthermore technical train data and emission factors are the same for all countries. In its present form therefore the model provides a limited level of differentiation between countries and no regional differentiation (except calculations per railway line).

3.3.7 Conclusion on emission factors for rail transport

The most important aspects for regional differentiations will be accurate information on composition of the train fleet (as shares in total transport performance), and quantification of regionally specific use characteristics expressed either in terms of typical energy consumption per train type or in terms of driving dynamics data on the one hand and occupancy / load factors (passengers or freight) on the other hand (for use in estimates of consumed energy).

In general it can be stated that available emission factors for trains are less versatile and sophisticated then the emission factor models available for road transport. Contrary to the situation for road transport, where detailed emission factor models are available for many countries, for rail transport only an overall modelling methodology is available in combination with rather aggregated data on energy consumption and emissions. The ARTEMIS model in its structure provides a basis for regional differentiation of emission factors, but would require major improvement efforts regarding data on train fleet composition and technical characteristics and emission factors of different train types.

4 Conclusions

4.1 Availability of transport flow and fleet data

Based on a review of data sources at the European level the current state of regional (sub-country) data availability on road and rail transport flow and vehicle fleet for EEA member states, is assessed as overall - moderate to poor with regard to the variables that are most relevant for emission inventories. Generally through European level sources no regional data at the level of vehicle kilometres or passenger and ton kilometres is available, let alone a further disaggregation into transport performance per vehicle class or road type. For a small group of other possibly useful transport indicators, however, the data availability is assessed as fairly good. Such data might be used to create geographically specific emission inventories in a rough approximation on the basis of additional modelling and assumptions. For many other indicators, data on a regional level is available only for a few countries. In general, data availability through international sources is higher for road transport than for rail transport.

A review of data availability through a limited number of national data sources shows that information on the relevant regional transport performance indicators may be available in national statistics, but is apparently not shared through international statistical databases. Further review of national data sources would be necessary to draw conclusions on the overall availability of useful regional data.

4.2 Regional differentiation of emission factors

Road

Emission factors such as available through the COPERT methodology in principle enable the modelling of regional variations with respect to:

- Fleet composition and transport performance per vehicle type.
- Ambient temperatures (and their impact on cold start emissions and evaporative emissions).

From the documentation it is not clear whether emissions related to airco use and regional variations thereof are taken into account in COPERT. Effects of traffic characteristics are included in COPERT through the selection of road type and variation of the variable ‘average speed’. Experience from the development of VERSIT+, however, has shown that modelling based on average speed alone can not accurately describe emission variations in relation to the level of congestion, driving styles or e.g. traffic measures influencing traffic flow. Given that COPERT is the prescribed model to be used for EU emission inventories the functionality of COPERT with regard to modelling variations in traffic characteristics could be used in first instance, but for the longer term the use of a new model or an update of COPERT (possibly on the basis of new models that are more advanced with regard to this aspect) would seem advisable.

Rail
The most important aspects for regional differentiations will be accurate information on composition of the train fleet (as shares in total transport performance), and quantification of regionally specific use characteristics expressed either in terms of typical energy consumption per train type or in terms of driving dynamics data on the one hand and occupancy / load factors (passengers or freight) on the other hand (for use in estimates of consumed energy).

In general it can be stated that available emission factors for trains are less versatile and sophisticated than the emission factor models available for road transport.

Contrary to the situation for road transport, where detailed emission factor models are available for many countries, for rail transport only an overall modelling methodology is available in combination with rather aggregated data on energy consumption and emissions.

4.3 Possibilities for regional differentiation of emission inventories

Overall it can be concluded that the possibilities to model regional differences in vehicle emissions is currently limited by the availability of regional statistics on vehicle fleet composition and transport performance on various road types rather than by the limitations of the COPERT emission factors model.

A more in-depth review of data availability at the national level is necessary to draw conclusions on the possibility of setting op geographically specific transport emission inventories on the basis of existing data. Such a review could be carried out by Eurostat in cooperation with national statistics institutes and could also comprise activities to further work out a methodology for regional data collection.

The database and modelling developed in the ETIS project seems to provide a useful starting point for setting up a Europe-wide inventory of regional transport emissions.

4.4 Overall conclusion

For the purpose of creating overviews of regional transport emissions for the moment no further improvement of emission factor models is necessary. Possibilities are currently limited by the lack of available relevant transport performance data at the regional level. This situation could be improved if data that are now only collected and maintained at the national level are made available through an international data source. Further significant work to fill gaps in the availability of various data seems to be unavoidable, however, both at the level of individual countries and an the European level.

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Geographically specific transport emission inventories

Review of feasibility for road and rail transport

Annexes

Report

Delft, December 2006

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A Other emission factor models for road transport

In chapter 3 the COPERT model is assessed in view of the data requirement and possibilities for regional disaggregation of emission inventories. As examples also some other available emission factor models are discussed in that chapter. Below a brief description is given of the main characteristics of the following models:

- German / Swiss / Austrian Handbook Emission Factors[23].
- ARTEMIS[24].
- VERSIT+[25].

German / Swiss / Austrian Handbook Emission Factors
The Handbook of emission factors for Road Transport (HBEFA) has been developed in co-operation between various institutes from Germany, Austria and Switzerland (RWTÜV, IFEU, TU-Graz, INFRAS) and is used in the emission inventories for these countries. provides emission factors, i.e. the specific emission in g/km for all current vehicle categories (PC, LDV, HDV and motor cycles), each divided into different categories, for a wide variety of traffic situations. The newest version 2.1 dates from February 2004. This new version provides emission factors for all 3 ‘D-A-CH’-countries (Germany (D), Austria (A) and Switzerland (CH)), split into ‘hot’ emission factors, excess cold start emissions and evaporation emissions (soak, diurnal). All relevant legislative concepts (up to Euro-5 for heavy duty vehicles) are covered. The handbook provides emission factors per traffic activity. Different levels of disaggregation are being offered:

- By type of emission: ‘hot’ emissions, cold start emissions, evaporation (hot/warm soak, diurnal).
- By vehicle category: passenger cars, light duty vehicles, heavy duty vehicles, buses and coaches, motorcycles.
- By year (1980-2020), and implicitly by varying fleet compositions in the three countries (Germany, Austria, Switzerland).
- By pollutants. Factors for the following components are provided: CO, HC, NO_x, PM, several components of HC (CH_4, NMHC, benzene, toluene, xylene), fuel consumption (gasoline, diesel), CO_2, NH_3 and N_2O.

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23 *Handbuch Emissionsfaktoren des Straßenverkehrs*, HBEFA 2.1, UBA Berlin / BUWAL Bern / UBA Wien, http://www.hbefa.net/ or http://www.umweltbundesamt.at/umweltschutz/verkehr/abgase/hbefa/.

24 ARTEMIS: Assessment of Road Transport Emission Models and Inventory Systems, http://www.trl.co.uk/artemis/index.htm.

25 *A New Modelling Approach for Road Traffic Emissions: VERSIT+ LD – Background and Methodology*, R. Smit et al., TNO Automotive, the Netherlands, TNO report nr. 06.OR.PT.016.1/RS, July 2006.

The so called 'hot' emission factors are being provided for several traffic situations and for different gradient classes (0%, 2%, 4%, 6%). HBEFA 2.1 provides also weighted average values (distributions over several traffic situations and gradient classes). The cold start emission factors are based on typical temperature distributions and behavioural parameters (such as trip length distributions, driving patterns at cold start).

ARTEMIS
ARTEMIS is an EU-funded project under the 5th Framework (DGTREN Contract 1999-RD.10429). The project started in January 2000 and was ended in 2005. The project was coordinated by TRL Ltd, UK. The goal of ARTEMIS was to develop a harmonised emission model for road, rail, air and ship transport to provide consistent emission estimates at the national, international and regional level. This goal has been achieved to different extents for the different transport sectors.

The main output of ARTEMIS for road transport are emission factor databases for light duty vehicles[26] (passenger cars and vans) and heavy duty vehicles[27] (trucks and buses). Emission factors for various vehicle classes (vehicle type, fuel, age) are given for a large number of so-called traffic situations. These traffic situations are based on a categorisation of combinations road types and traffic intensities. Road types include detailed subdivisions of different road types (e.g. regarding number of lanes, speed limit and curvature) that exist in urban, rural and highway situations. These road types can be used to characterise road segments in a road network. For all road types driving cycles (speed-time patterns) have been derived that have been used to measure and model vehicle emissions. The output from ARTEMIS thus enables regional differentiation with respect to:

- Fleet composition.
- Composition of the road network.
- Traffic intensities and corresponding effects on emissions.

In the context of the ARTEMIS-project a large number of emission measurements has been performed. Data from these measurements are being used as input for the update of the emission functions underlying COPERT III, resulting in COPERT 4.

VERSIT+
The model VERSIT+ has recently been developed by TNO. It replaces the VERSIT model which has been used for more than 10 years as the source of road vehicle emission factors in the Netherlands. The passenger car module, VERSIT+ LD, is based on an advanced statistical analysis of a database of vehicle emission measurements carried out on a large number of vehicles using a wide variety of test cycles derived from driving patterns recorded on the under various real world driving conditions. The core of the model is a module with regression functions that calculate hot running emissions of vehicles of different

[26] ARTEMIS WP 300: Establishment of reliable emission factors for passenger cars and light duty commercial vehicles.

[27] ARTEMIS WP 400: Establishment of reliable emission factors for heavy duty road vehicles.

Euro classes as a function of a set of variables characterising the (dynamics of the) driving pattern. Furthermore the model comprises modules to:

- Calculate cycle variables on the basis of a speed-time pattern provided as input to the model.
- Modules to calculate cold start emissions and the effects of ageing and the use of air conditioners.
- Aggregate emission factors for separate vehicle classes into emission factors for a traffic flow, using fleet composition data.

A separate module has been developed for light duty commercial vehicles (vans).

The model for trucks and buses, VERSIT+ HD, is based on the PHEM emissions simulation model developed by TU-Graz[28], and contains modules to assess emission factors that are specific for various vehicle types and classes for e.g. the situation in the Netherlands. Though different in underlying methodology the functionality of the LD and HD modules are compatible.

On of the advantages of the model is that it is able to assess the impacts of changes in driving dynamics on vehicle emissions. Driving dynamics is determined by driving style, vehicle characteristics and traffic characteristics. VERSIT+ may thus e.g. be used to assess the impacts of traffic measures on fuel consumption and emissions.

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28 See e.g.: Hausberger S., Rexeis M.: *Emission behaviour of modern heavy duty vehicles in real world driving*, International Journal of Environment and Pollution, 2004; Hausberger S.,Rodier J., Sturm P., and Rexeis M.: *Emission factors for heavy duty vehicles and validation by tunnel measurements*, Atmospheric Environment 37 (2003), p. 5237 – 5245.

B The ARTEMIS-model for rail transport

Within the ARTEMIS-project[29] the Technical University of Denmark, which was also responsible for the MEET rail emissions model[18], has developed a new methodology and model for rail emissions[30]. The model structure is graphically displayed in Figures B1 and B2.

The core of the model calculates energy consumption and emissions for a given train type on a specific railway line (section between two stations). The model discerns 5 different train types (HST / Inter City / Regional / Urban / Freight). Trains are furthermore specified by the vehicle type (HST / locomotive / railcar) and the traction type (electric / diesel). Energy consumption on a railway line is calculated on the basis of the following inputs:

- Technical characteristics of the train (e.g. weight, resistance factors, frontal area, number of seats, train length and mass).
  - The model contains default values for these characteristics but they can also be specified by the user.
- A load factor for the train type (occupancy % and tonnes/seat for passenger trains, tonnes per tonnes of goods for freight trains).
- A VA-matrix of the speed profile for the given railway line and train type. The VA-matrix describes the % of time or distance (both methods can be used in the model) that the train drives with a speed V and acceleration A with a given interval.
  - The model contains default average VA-matrices for the different train types (based on an analyses of detailed speed-time patterns recorded in Denmark), but specific VA-matrices can also be specified by the user.
- Characteristics of the railway line, e.g. line length, max. gradient, tunnel distance, max. speed for passenger trains, max. speed for freight trains, and difference in altitude between start station and end station.

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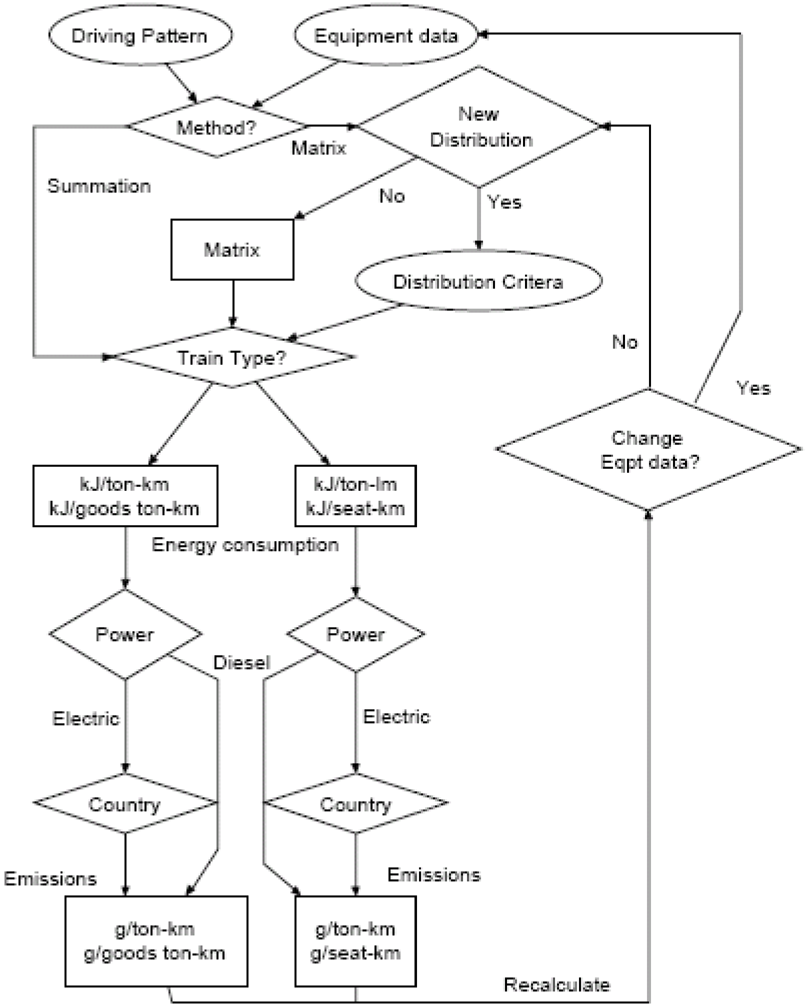
29 http://www.trl.co.uk/artemis.

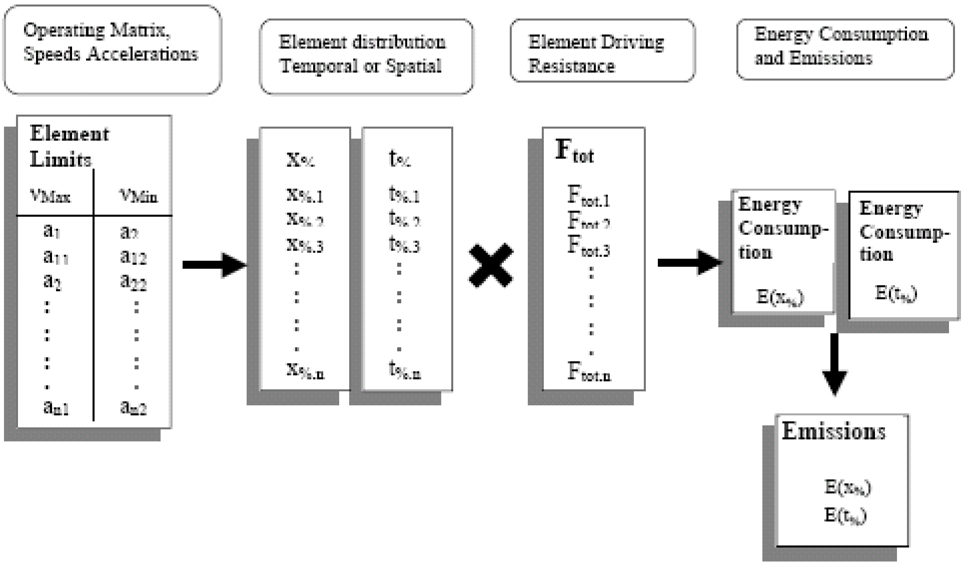
30 ARTEMIS WP700 *Emission estimating methodology for rail transport*, http://www.trl.co.uk/artemis/index.htm
Simulation of Energy Consumption and Emissions from Rail Transport, S.C. Sorensen et al., WP 700 final report, Feb. 2005; *Simulation of Energy Consumption and Emissions from Rail Transport - Software Package User's Manual*, T.M. Cordeiro et al., Feb. 2005.

Figure 1	Flow diagram of the ARTEMIS rail emissions model[22]



Using these data the power and energy consumption is calculated for each cell of the VA-matrix. The results per cell are summed to achieve the total energy consumption over the line. Emissions are calculated by multiplying the energy consumption in GJ with emission factors for diesel engines or electricity generation in g/GJ.

Figure 2 Methodology for estimating energy consumption and emissions over a railway line section in the ARTEMIS rail emissions model



In principle the model allows various levels of regional differentiation:

- Because emissions are calculated per railway line or segment, regional emissions can be calculated by adding all emission from railway segments in a given region.
- Regional differences in train characteristics can be specified by the user.
- Emission factors can be modified by the user to represent specific diesel trains or regionally specific characteristics of electricity generation. In this process also effects of e.g. fuel quality and ambient conditions can be taken into account, provided that relevant information is available.
- Regional differences in driving dynamics can be modelled by specifying railway line specific or region specific VA-matrices.
- Regional differences in traffic intensities, occupancy factors can be specified by the user.

Calculating regional emissions from rail transport in this way requires the availability and input into the model of region specific data as listed above and may also require some modifications to be made to the model software.